Footstep Power Harvesting for Soil Irrigation

Dissertation submitted to
Visvesvaraya National Institute of Technology, Nagpur
In partial fulfilment of the requirements for the award of the degree

Master of Technology
in
VLSI Design

by

DEUSH UDAY HINGE
(MT23MVD020)

Under the guidance of

Dr. GANESH C. PATIL
Associate Professor

Center for VLSI and Nanotechnology
Visvesvaraya National Institute of Technology
Nagpur 440010, (India)
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Declaration

I, **DEUSH UDAY HINGE**, hereby declare that this dissertation titled "**Footstep Power Harvesting for Soil Irrigation**" is carried out by me in the Department of **Center for VLSI and Nanotechnology** of Visvesvaraya National Institute of Technology, Nagpur. The work is original and has not been submitted earlier whole or inpart for the award of any degree/diploma at this or any other Institution / University. no part of this work shall be published anywhere without written permission of the Dr. Ganesh C. Patil.

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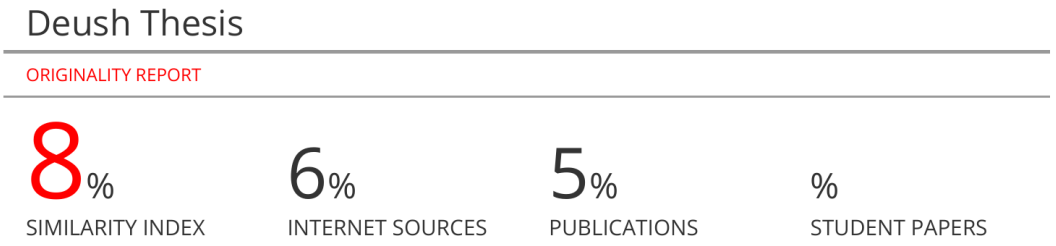

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Deush Uday Hinge

Abstract:

In densely populated places, water inefficiency and urban energy scarcity are major problems. By using solutions from piezoelectric technology, this study tackles these issues. Using piezoelectric sensors and Arduino microcontrollers, the device uses foot pressure in high-traffic areas to generate mechanical energy. Using real-time soil moisture data, the captured energy is stored and used to power automated gardening devices. This two-pronged strategy improves sustainability by managing irrigation to save water and turning mechanical energy produced by footsteps into electrical power. The project's goal is to lessen the operational expenses and environmental effects of traditional energy sources and water management techniques. The continuous expenses incurred in the day-to-day operation of water and energy networks are operational expenses. This covers the purchase, upkeep, and labour of fuel for conventional energy sources like coal and oil. Pumping, treatment, distribution, and infrastructure maintenance are all included in water management costs. The effects on the environment include that Conventional energy production frequently results in habitat damage, air and water pollution, and greenhouse gas emissions. In a similar vein, traditional water management practices may contribute to excessive water resource exploitation, untreated wastewater contamination, and high energy use that increases emissions. The system showed great promise over a six-month period, using 30% less water than conventional techniques and offering a dependable power supply for automated gardening. Through effective management of energy and water resources, this creative application tackles current urban issues and promotes long-term environmental sustainability.

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Abbreviations:

MCU: Microcontroller Unit

VCC: Voltage Common Collector

GND: Ground

LED: Light Emitting Diode

PZT: Lead Zirconate Titanate

PVDF: Polyvinylidene fluoride

PDMS: Polydimethylsiloxane

IDE: Integrated Development Environment

SPDT: Single Pole Double Throw

AC: Alternating Current

DC: Direct Current

RTD: Resistance Temperature Detector

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1

INTRODUCTION

1 INTRODUCTION

1.1 Soil Irrigation:

Water is delivered to the plant's root zones by soil irrigation, which guarantees that the plants have enough moisture for germination, nutrient uptake, and photosynthesis. The main objective is to maintain plant health and productivity by augmenting natural precipitation, especially in arid regions or during dry periods. In order to maintain proper soil moisture levels, irrigation entails giving plants water at regular intervals. This method supports steady agricultural output and makes up for erratic rainfall patterns. Surface irrigation, sprinkler systems, drip irrigation, and subsurface irrigation are some of the diverse irrigation techniques that are appropriate for various soil types, crops, and environmental circumstances. Even in areas with little or irregular rainfall, irrigation guarantees healthy crop growth and increased yields by supplying a steady supply of water. Food security is ensured by irrigation, which shields crops from the damaging effects of droughts and seasonal water shortages. The amount of arable land available can be increased by converting formerly uncultivable areas into productive agricultural areas by irrigation. For plants to thrive, soil structure and nutrient availability must be maintained by appropriate irrigation techniques.

1.2 Need of Soil Irrigation:

Year-round farming is made possible by irrigation, which extends the time that crops can be grown beyond periods of

natural rainfall. Consistent irrigation moisture preserves soil integrity and reduces soil erosion. Drip systems and other contemporary irrigation techniques reduce water waste by supplying water straight to plant roots. By eliminating the need for manual watering, automated irrigation systems save time and effort. Regular watering schedules result in more consistent crop growth and higher quality. Adopting efficient soil irrigation techniques is essential for sustainable farming, particularly in areas with limited water supplies. Irrigation greatly aids in environmental preservation and food security by maximizing water utilization and preserving soil health.

1.3 Power Harvesting:

The process of absorbing and transforming ambient energy from the environment into usable electrical energy is called power harvesting, sometimes referred to as energy harvesting or energy scavenging. This method is especially useful for supplying energy to tiny, low-power electronics like wearables, sensors, and Internet of Things (IoT) devices without the need for conventional power sources like batteries or external electrical connections. Power harvesting focuses on how quickly energy is gathered and used, which is important for applications that need a steady and uninterrupted power source. This is especially important for gadgets that require a steady stream of energy to function properly. For example, in the context of wearable electronics or wireless sensor networks, the emphasis is not only on the overall amount of energy gathered over time, but also on making sure that the power (energy per unit time) is adequate to maintain uninterrupted operation of the device. Power harvesting

thus emphasizes the significance of energy amount and supply rate.

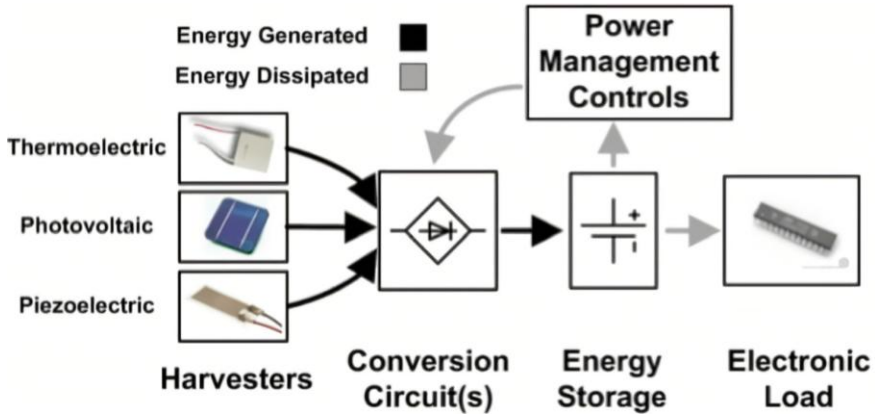

Figure 1.1 Energy Harvesting for Low-Power Applications

1.4 Concept of Footstep Power Harvesting:

Footstep power harvesting is a cutting-edge technique that uses the kinetic energy generated by walking to generate electricity. Specialized devices placed beneath walking surfaces can transform this energy—which is usually lost as heat or absorbed by flooring materials—into electrical power. The basic idea is to transform the mechanical energy of footsteps into electrical energy. There are several ways to accomplish this. Mechanical tension causes piezoelectric materials to produce an electric charge. When buried in floor tiles, foot pressure causes deformation that generates electrical energy. A footstep's linear motion is transformed into rotational motion by electromagnetic mechanisms, such as rack and pinion arrangements, which power a generator to generate electricity. Some designs drive turbines or generators by using fluid displacement brought on by foot pressure. Devices like LED lights can be powered instantly by the produced electricity, or it can be saved for later

use in batteries or capacitors. In populous places, it makes use of human mobility, a steady and renewable energy source. By enhancing conventional power sources, it helps reduce greenhouse gas emissions. Captures energy that would otherwise be wasted, increasing energy use in general. Public engagement and education regarding renewable energy practices can be achieved through visible implementations. A UK-based startup named Pavegen has created floor tiles that use footsteps to create electricity, which powers interactive displays and lamps. Additionally, footstep power harvesting can be linked into some public infrastructure, such as train stations and public walkways, to power information screens and brighten regions.

1.5 Piezoelectric Effect:

The phenomenon known as the piezoelectric effect occurs when mechanical stress or pressure causes some materials, also referred to as piezoelectric materials, to produce an electrical charge. In crystalline materials without inversion symmetry, this phenomenon is caused by the direct interaction between the mechanical and electrical states. An electrical potential is created when these materials are distorted because the interior molecular structure becomes polarized, separating the positive and negative charges. The existence of electric dipole moments in solids is intimately linked to the characteristics of the piezoelectric effect. The reverse piezoelectric effect, in which an electrical field induces mechanical deformation in the crystal, is another effect that piezoelectric materials exhibit. The distinctive ability of piezoelectric sensors to produce energy in response to changes in vibration or pressure sets them apart.

The capacity of small devices to produce energy from many mechanical energy sources, including human actions like walking, makes them appropriate for all applications. The concept of footstep power generation involves placing piezoelectric sensors beneath the floor or steps to detect the kinetic energy generated by footfall. This energy is then transformed into usable electrical power, hence lowering global energy consumption

1.5.1 How the Piezoelectric Effect Works

Piezoelectric materials have an atomic-level crystal structure devoid of a center of symmetry. Positive and negative charge centers separate as a result of the crystal lattice being distorted by mechanical stress such as compression, tension, or vibration. A voltage is produced across the material as a result of this separation, which produces an electric dipole. This technique is reversible because the material changes shape when an electric field is applied, allowing for precise mechanical movements.

1.5.2 Common Piezoelectric Materials

One naturally occurring mineral that is renowned for its accuracy and stability is quartz (SiO_2). Because of potent piezoelectric qualities, lead zirconate titanate (PZT) is a synthetic ceramic that finds extensive application. Another ceramic substance with noteworthy piezoelectric properties is barium titanate ($BaTiO_3$). PVDF, or polyvinylidene fluoride, is a flexible polymer that can be used in pliability-demanding applications.

1.5.3 Applications of the Piezoelectric Effect

Utilized in a variety of applications, the piezoelectric effect transforms mechanical impulses into electrical ones in devices such as pressure sensors, accelerometers, and microphones. used as an actuator in applications requiring precise movement, such inkjet printers and camera autofocus systems. Used as medical devices to produce and receive sound waves in ultrasonic imaging equipment. Generates electrical power by harnessing mechanical energy from sources like as footsteps or vibrations, which is helpful for energy harvesting in small electronic devices. Found in consumer electronics such as touch-sensitive switches, electric lighters, and pickups for musical instruments.

1.6 Sensor:

A sensor is a device that detects and reacts to changes in its environment by converting physical stimuli like heat, light, motion, or pressure into electrical signals for measurement or control purposes. A sensor is also referred to as a transducer, which is an apparatus or element that recognizes or quantifies a physical quantity and transforms it into an electrical or digital signal. Figure 1.2 explains the internal blocks of a sensor. Many industries, including engineering, science, agriculture, business, the medical field, and consumer electronics, use sensors to track and gather data about the immediate environment or specific situations. Sensors are essential to modern technology because they allow systems to effectively monitor and interact with their surroundings.

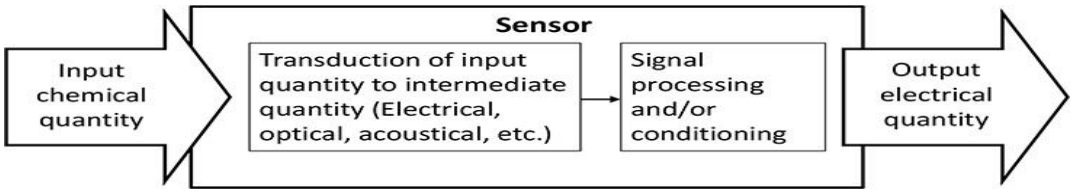
Sensor
Input chemical quantity
Transduction of input quantity to intermediate quantity (Electrical, optical, acoustical, etc.)
Signal processing and/or conditioning
Output electrical quantity

Figure 1.2 Block diagram of Sensor

Sensors can detect a wide range of physical attributes, including temperature, light intensity, motion, sound, humidity, acceleration, proximity, and pressure. They can function via optical, chemical, electromagnetic, electrochemical, mechanical, or thermal principles, depending on the type of sensor and the quality being assessed. A sensor's output may be an electrical voltage, frequency, current, or digital signal that other hardware, software, or systems could process, analyze, or use. Robots, the Internet of Things (IoT), automation, control system applications, and other technologies that depend on data collecting and physical event observation all require sensors.

1.7 Types of sensors:

As shown in Fig. 1.3, there are numerous types of sensors that can be employed. They are all designed to identify and quantify specific physical attributes or measurements. A temperature sensor is used to measure the temperature of the immediate surroundings. Examples include thermistors, resistance temperature detectors (RTDs), and thermocouples. sensor to measure and identify pressure variations, Pressure sensors include strain gauge sensors, piezoresistive sensors, and capacitive sensors. A light sensor determines the intensity of the surrounding light. Examples include ambient light sensors, photodiodes, and phototransistors. A proximity sensor can

identify an object's presence or proximity without physical contact. A few examples are inductive, capacitive, and ultrasonic sensors. Acceleration or variations in velocity are measured with an accelerometer. utilized in applications including motion recognition, direction detection, and vibration assessment. Gyroscopes are used in virtual reality devices, navigation systems, and robot programming to detect rotational or angular movement. A magnetic sensor is used to measure and identify magnetic fields. Examples include Hall effect sensors and magneto resistive sensors. A moisture sensor determines the air's relative humidity, sometimes known as its moisture content. Examples include resistive and capacitive moisture sensors. A gas sensor is used to detect the presence or concentration of a particular gas in the environment. Examples include sensors for carbon monoxide, oxygen, and methane. Motion sensors are used to detect and measure sound waves or sounds using sound sensors. Microphones and sound-level meters are two examples. In addition to providing information on human-needed characteristics, a water sensor will identify various water contaminants and minerals. These, however, are only a handful of the numerous specialized sensors designed for particular applications. With the ongoing advancement of sensor technology, new types of sensors are being developed to meet the evolving needs of many industries and fields.

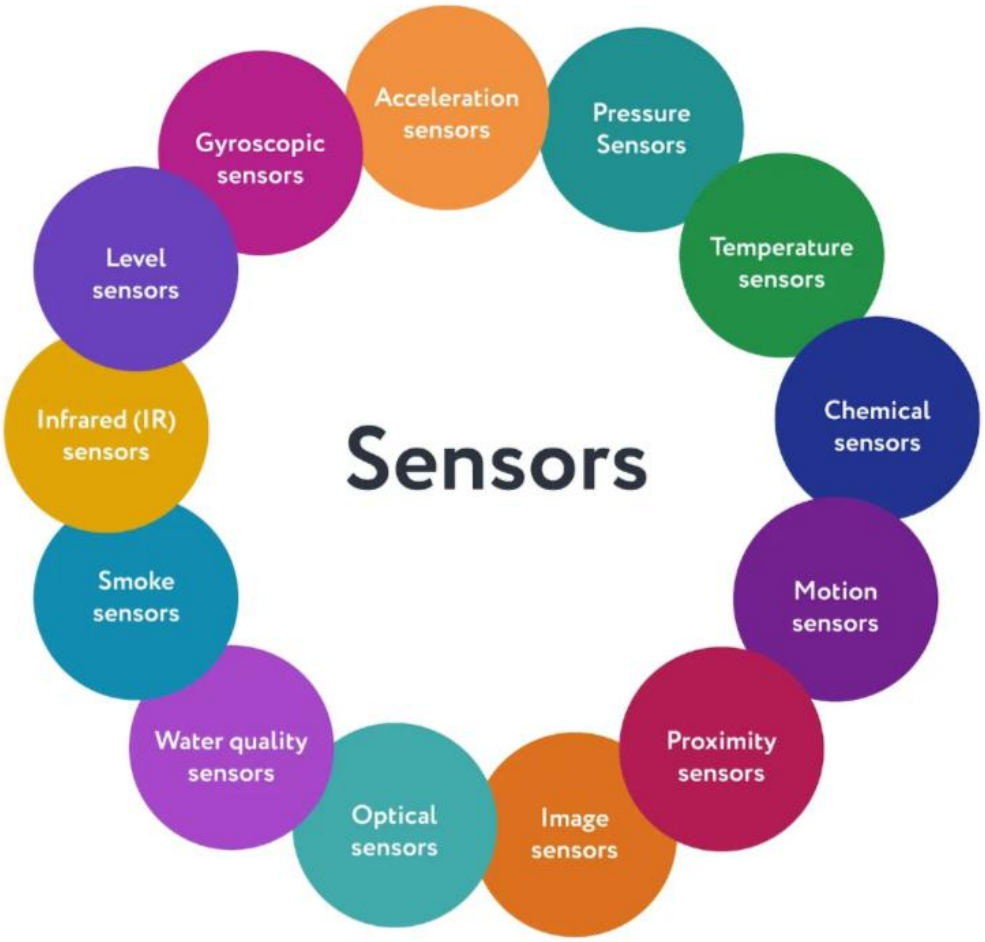

Figure 1.3 Types of sensors

1.8 Project Overview:

It is well known that people enjoy walking, which is why walking energy is now being converted into electricity rather than using the required fossil fuels. This is because countries like India, which have dense populations, will benefit greatly from walking. Currently, most of India has irregular and inadequate energy systems, so this movement or transition of people into electrical forms is considered to be one of the

technologies of the future. As energy harvesting moves from traditional to nontraditional energy sources like motion, environmental damage decreases but efficiency increases. On the other hand, if she or he grasps it with both hands, this is a well-defined, strategically sound endeavor that will level the playing field. In order to preserve water, the project's primary purpose is to use human motion to create energy that is subsequently stored in a battery and used to water the plant. The nation’s economic growth can be significantly accelerated by the generator power component of solar-based power generation. Through proactive use of piezoelectric sensor plates, Arduino Uno MCU, and relay modules, this project proposal aims to relate to the feasibility and authenticity of footstep power generation in the field of renewable energy. The system will be able to use the power from human steps to power various applications, including water management, such as automatic garden watering, where soil moisture sensors are used to determine the amount of water required, and motor pumps are activated by using piezoelectric plate power, which generates energy. By integrating all of these components, the project not only demonstrates the feasibility and potential of footstep power generation as a potential energy crisis solution, but also its suitability for both urban and rural settings.

1.9 Organization of thesis:

The objective of thesis is to develop a system of footstep power harvesting for soil irrigation. For this we made a system and tested in software with hardware implementation.

Chapter 1:

In this chapter, introduction to the project thesis is given and discussion brief about soil Irrigation, Concept of footstep power harvesting, sensor, types of sensors and overall project overview

Chapter 2:

In this chapter, the literature survey on the footstep power harvesting for soil irrigation is discussed.

Chapter 3:

This chapter gives methodology in which circuit diagram, Architecture diagram, Algorithm and Piezoelectric material with working is discussed.

Chapter 4:

This chapter shows implementation in which both software and hardware are implemented

Chapter 5:

This chapter discusses about the state of the art implementation in which previous work and proposed work is discussed.

Chapter 6:

This chapter provides limitations to work.

Chapter 7:

In this chapter, we discussed about the results of the work.

Chapter 8:

Conclusion and future scopes are discussed in this chapter.

Chapter 9:

This chapter gives references.

2

LITERATURE REVIEW

2.1 Literature Survey:

This chapter includes the work that has been done by different researchers on the topics related to footstep power harvesting for soil irrigation.

To guarantee that wearable energy harvesting solutions are being developed effectively, Ganesh et al. [1] describe how mechanical energy is exploited to generate electricity with the aid of piezoelectric sensors placed in footwear, which are then used to charge mobile phones and other small gadgets.

The effectiveness of a shoe-integrated power generation system is explained by Pandit et al. [2]. To assess the mechanical energy generated by walking as a renewable energy source that would always have positive effects on the urban atmosphere, they used piezoelectric sensors.

Fauzi et al. [3] discuss how piezoelectric sensors can be used to improve footstep power generation. The paper's contribution centers on the possible use of continuous street lighting and other electrical applications to improve urban sustainability.

Sanjit et al. [4] explain how piezoelectric sensor array characteristics affect the amount of power generated by footsteps and offer suggestions for improving technology in relation to running and walking. Sensor density and material properties are the criteria used to maximize energy generation in various running or walking situations.

By concentrating on improving voltage and power generation from footsteps, which call for a low voltage input, Khan et al. [5] outline configurations for multi-array piezoelectric transducers for portable applications, advancing the development of effective systems for the energy harvesting of

mobile device power.

The design and execution of a human footstep power harvesting system employing piezoelectric sensors are covered by Vardhini et al. [6]. This system uses the captured energy to generate renewable energy, with the ultimate goal of managing the harvested energy using battery systems.

In order to demonstrate that there are multiple methods for creating energy responsibly, Dalabeih et al. [7] suggest using piezoelectric floor tiles that can absorb kinetic energy when a person steps on them. This allows for the provision of clean energy for a variety of applications.

Albaw et al. [8] suggest an Internet of Things (IoT)-based footstep power generator that contributes to the development of intelligent energy management systems by boosting security and productivity through precise energy monitoring and control.

Mohammed et al. [9] look into the potential of a footstep power generation method that controls a boost converter with a self-biased piezoelectric oscillator. Stepping on these tiles efficiently converts mechanical energy from footfall into electrical energy for the creation of sustainable smart city power. As a result, it demonstrates how well the system works to sustain and autonomously regulate the DC voltage output of the photovoltaic cells without the need for outside bias, making it a sustainable energy source for urban settings.

Because of the overuse of non-renewable resources, Praanesh et al. [10] emphasize the necessity of developing renewable energy sources. With the aid of transducers, it has suggested piezoelectric power generation as an alternative. The hardware prototype has been developed and documented in this work, along with a description and simulation of the system's outline

using MATLAB/Simulink. The system comprises piezoelectric transducers, a full-wave rectifier, and a SEPIC converter.

In addition to discussing energy management in the hybrid renewable energy system (HRES), Bajpai and Dash [11] draw attention to the stochastic nature of renewable energy sources. In addition to being easily incorporated into automated gardening, it may give an overview of how piezoelectric plates can be utilized to transform mechanical stress, such as walking or running, into electrical energy.

Methods to enhance food production to meet people's needs are described by Srilikhitha et al. [12], particularly in India, where agriculture is widely practiced. To be self-sufficient and regulate water loss, they implement a smart irrigation system that includes a microcontroller, a relay motor, an ADC, temperature and moisture sensors, and more. Also, an LCD reveals field data, while a GSM modem delivers status updates on the motor to farmers, which is an affordable design that is useful in areas of water constraint.

An Internet of Things system for continuous soil health monitoring is proposed by Ramson et al. [13]. It consists of solar-powered soil health monitoring units (SHMUs) that are linked to the Internet using the LoRaWAN protocol. They came to the conclusion that power consumption, sensor inclusion modularity, and long-term operation appropriateness are all improved. Therefore, by adding a renewable energy source for SHMUs that would continuously monitor and maintain the soil health of the garden, the integration of piezoelectric power generation can enhance automated gardening.

Depending on the smart irrigation warning system, Lalitha et al. [14] take into account the issues of water conservation and

irrigation process automation to minimize human input in specific areas. The system has sensors for measuring soil moisture; if the moisture content drops below a predetermined point, the system sounds an alarm and irrigates the plants, allowing users to manage the process from a distance.

Saranya et al. [15] provide a thorough analysis of the energy storage system utilizing piezoelectric sensors for park lighting, irrigation, and mobile charging services, and they further develop it with the aid of IoT for ongoing monitoring and assessments in the future.

By putting piezoelectric sensors inside a 3-meter mat, Yashout et al. [16] suggested a sustainable power generating system that can generate electricity from footsteps and store it in a rechargeable battery. Live notifications are provided by an Internet of Things-based monitoring system through the Blynk smartphone app. After twenty hours of continuous stepping, the system can charge a 7000 mAh battery with 1.1 mW per step.

Thangam et al. [17] outline the prospective strategy of employing IOT devices such as NodeMCU, DHT11 sensors, and soil moisture sensors for agriculture in order to effectively regulate water use. Additionally, intelligent water use is made possible by automatic water control based on real measurements of soil moisture content, which is essential for environmentally friendly farming practices and sustainable environmental management.

Virupaxappa and Thangam [18] emphasize how IoT is revolutionizing agriculture, especially in the area of water conservation. Irrigation techniques are optimized by accurate soil moisture level monitoring and control made possible by IoT-enabled sensors and automated systems. Additionally, it

boosts crop yields while simultaneously lowering water consumption, which is crucial for sustainable agriculture.

Depending on the environmental conditions, Dandu and Thangam [19] talk about how IoT might improve solar PV systems efficiency. This method illustrates how both approaches improve energy savings in sustainable agriculture since it builds upon the ideas of piezoelectric energy collection.

3

METHODOLOGY

3.1 Circuit Diagram:

The Circuit involves six piezoelectric sensors connected in series and parallel combination to get required output. Arduino Uno serves as the system's main processor and is able to decipher sensor data and carry out preprogrammed commands. Jumper wires make it easier to connect parts. The soil moisture sensor uses electrical resistance to measure moisture levels. It has two probes that are put into the soil. The sensor is powered by a wire (VCC) that connects to the Arduino's 5V pin, and the ground connection is made by a wire (GND). Resistance data is transmitted by connecting the analog output of the sensor to pin A0 of the Arduino's analog input. To safeguard the LED, which acts as a visual indicator of soil moisture levels, a resistor (designated "100") controls current. Activation based on preset thresholds is made possible by its connection to the digital pin of the Arduino. Sensor readings are interpreted by Arduino code to initiate actions, like sending moisture data to external displays or turning on the LED for dry soil. Motor is connected to Arduino Uno through relay module. The rechargeable battery is also connected to the system. Tinkercad is used to outline the circuit schematic in Figure 3.1.

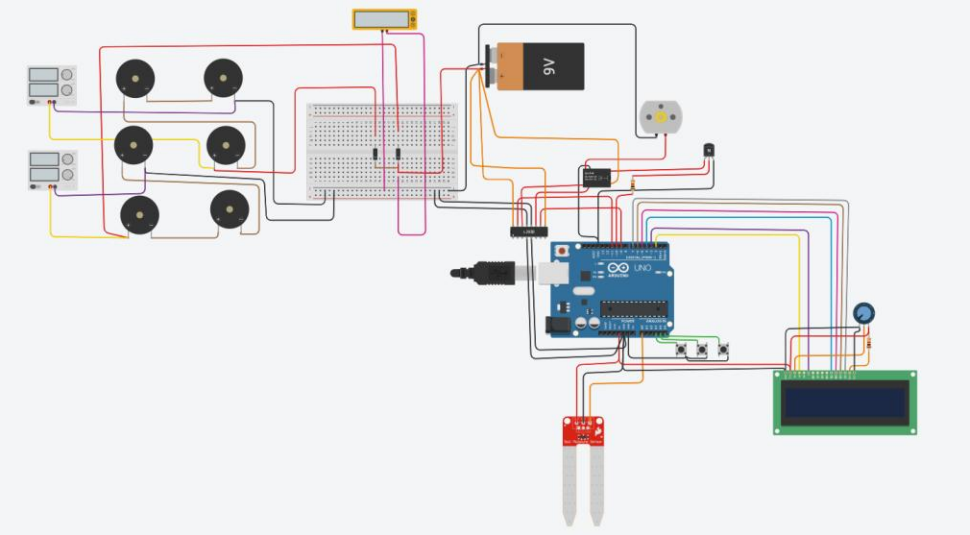

Figure 3.1 Circuit Diagram

3.2 Architecture Diagram:

Figure 3.2 below shows how an Arduino Uno microcontroller board and a soil moisture sensor are integrated to track and react to soil moisture levels. The Arduino Uno, which serves as the system's central processing unit, is at its heart. It uses the uploaded code to run pre-programmed commands after reading data from the soil moisture sensor. Two probes that are put into the soil to measure its electrical resistance—which changes depending on the moisture content—make up the soil moisture sensor. The sensor is grounded using a GND and powered by a VCC that is attached to the Arduino's 5V pin. Furthermore, sensor data is sent to the Arduino's analog input pin via an analog cable, giving real-time feedback on the moisture content of the soil. An LED, which can potentially be attached to an Arduino digital pin, has its current flow restricted by a resistor. As a visual signal, the LED illuminates in response to preset

parameters, including dry soil. The technology has potential uses in gardening, agriculture, and environmental monitoring since it can automate responses to soil moisture readings using specially written Arduino code.

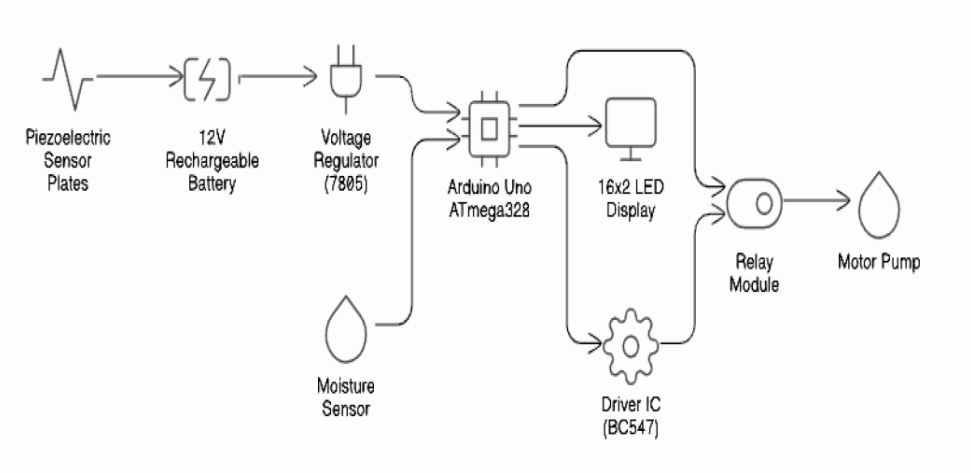

Figure 3.2 Architecture Diagram

3.3 Algorithm:

The algorithm used for the system implementation is shown below:

Result: Efficient garden watering using energy generated from footsteps.

Input: Soil moisture data, mechanical stress data from piezoelectric sensor plates, battery voltage level.

Output: Soil moisture level, system status updates, water pump control status.

Initialize System: Setup and test all components.

Energy Generation: Monitor mechanical stress from piezoelectric sensor plates and convert it into electrical energy. Store generated energy in the battery.

Start while True **do**

Moisture Level Monitoring: Read soil moisture level using the moisture sensor.

if Soil moisture is dry **then**

Motor On: Then the plant gets watered upto a certain threshold using the power from the battery which also stored energy from piezoplates.

end

Power Generation: Check the power in the battery.

if Power is less and the motor is not getting on **then**

Apply Pressure: Then apply pressure continuously on piezoplates.

end

Power and irrigating water The power generated is used and motor is controlled using relay and the automated gardening

Power supply Supply generated power for irrigating or gardening the plants.

end

3.4 Calculations:

Calculate the Force Applied:

Weight: 50 kg

Acceleration due to Gravity (g): 9.81 m/s^2

Force (F): $F=Weight \times g=50\ kg \times 9.81\ m/s^2$

$F=490.5\ N$

Charge Generated by One Disc:

Piezoelectric Coefficient (d33): 500 pC/N (assumed value for PZT)

Charge (Q): $Q=d33 \times F=500\ pC/N \times 490.5\ N=245{,}250\ pC$

$Q=245.2\ nC$

Voltage Calculation:

Capacitance (C): Assume each disc has a capacitance of 100 nF (nanofarads).

Voltage(V):

$V=Q/C=245.2\ nC/100\ nF=245.2 \times 10{-}9\ C/100 \times 10{-}9\ F$

$V=2.45\ V$

Let's calculate the total current consumption for 2 sensors:

Arduino Uno: 50 mA

LCD Display: 20 mA

Relay Module: 100 mA (worst case)

Motor: 200 mA (worst case)

Sensors: 2 sensors at 20 mA each = 40 mA

Total current consumption = 50 + 20 + 100 + 200 + 40 = 410 mA

The system is powered by a 3.7V supply, we can calculate the total power budget using the formula:

Power (W) = Voltage (V) x Current (A)

Total power budget = 3.7V x 0.41A = W

Therefore, total power budget of the system is approx. 1.5 W

3.5 Piezoelectric Materials and Working:

The capacity to exhibit the piezoelectric effect distinguishes piezoelectric materials from other types of substances. The capacity of some materials to generate an electric charge in reaction to mechanical stress is known as piezoelectric effect. On the other hand, applying an electric field to certain materials can also cause physical deformation.

These material's capacity to effectively convert mechanical energy to electrical energy makes them widely used in a variety of applications, including speakers, microphones, ultrasound imaging, and atomic force microscopy. Ceramics like lead zirconate titanate (PZT), polymers like PVDF, and composite materials like PZT-PVDF and PZT-polydimethylsiloxane (PDMS) are all examples of piezoelectric materials, each having unique benefits and disadvantages. Polymers are more flexible but have poorer piezoelectric performance, while ceramics have high piezoelectric coefficients but are brittle.

In the circuit diagram of figure 3.3, the piezoelectric diaphragm is used to activate when a button is pressed. A voltage is produced by the piezoelectric when the diaphragm's air content decreases. Following another transfer of this voltage into the circuit, the piezoelectric elements either accept or reject electrons, which further deforms the piezoelectric charge diaphragm. The economy as a whole is expanded by the products and services generated by manufacturing operations. It is possible to sketch a circuit where the piezoelectric diaphragm oscillates at its resonance frequency.

Ceramic materials such as lead zirconate make up the class of

piezoelectric materials. Lead titanate (PZT) with a polymer called polyvinylidene fluoride (PVDF) give piezoelectric activity, such as piezoelectric devices (PZT-PVDF, PZT/polydimethylsiloxane (PDMS)) and lead titanate, each of which has unique characteristics, benefits and disadvantages. The high piezoelectric coefficients found in ceramics are brittle, whereas polymers are distinguished by their elasticity and suppleness. Despite enabling multifunctionality, their outputs are comparatively weaker.

The more the material's contribution to the generation of electricity, the higher its piezoelectric constant value. For the same amount of mechanical stress, more electrons will be formed if the voltage is higher. PZT rises the highest. The following is the piezoelectric constant for the four materials mentioned above. This implies that mechanical stress will generate piezoelectric voltages more effectively the higher the degree of piezoelectricity. Piezoelectric materials have been used in sensors, medical imaging, energy harvesting, and other areas. They are useful for self-powered devices since they are frequently employed in nanogenerators, which transform mechanical energy into electrical energy. They support micro-weight measurements, gas detection, and virus detection (including COVID-19) in analytical chemistry. Furthermore, PVDF-based piezoelectric materials are becoming more and more popular because of their environmental friendliness and flexibility, which makes them appropriate for biomedical and wearable electronics applications.

The goal of recent developments is to increase the longevity and efficiency of piezoelectric materials. To improve their electromechanical qualities and increase their usefulness for

energy harvesting and sensing applications, researchers are investigating novel fabrication approaches. Another emerging trend is the creation of self-powering gadgets with piezoelectric materials in an effort to lessen dependency on outside power sources.

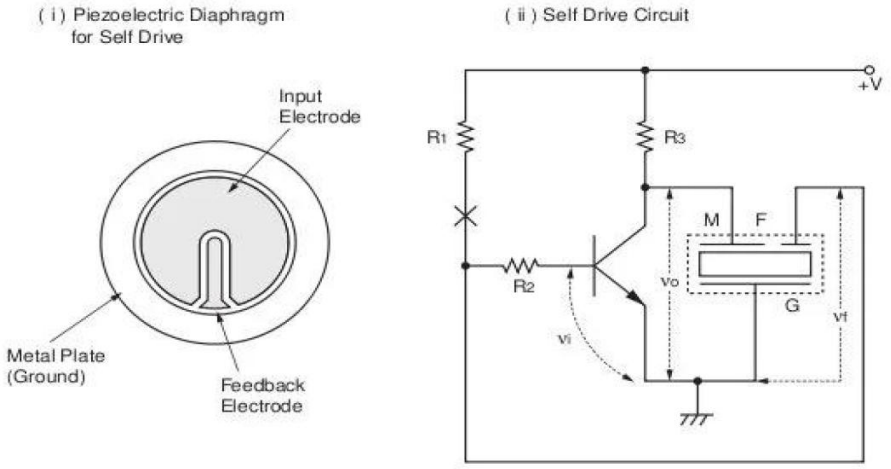

Figure 3.3 Schematic representation of piezo plate

The more the material's contribution to the generation of electricity, the higher its piezoelectric constant value. For the same amount of mechanical stress, a higher voltage will result in the formation of more electrons. For example, look at Fig. 3.4. PZT rises the highest. The following is the piezoelectric constant for the four materials mentioned.

This implies that mechanical stress will generate piezoelectric voltages more effectively the higher the degree of piezoelectricity.

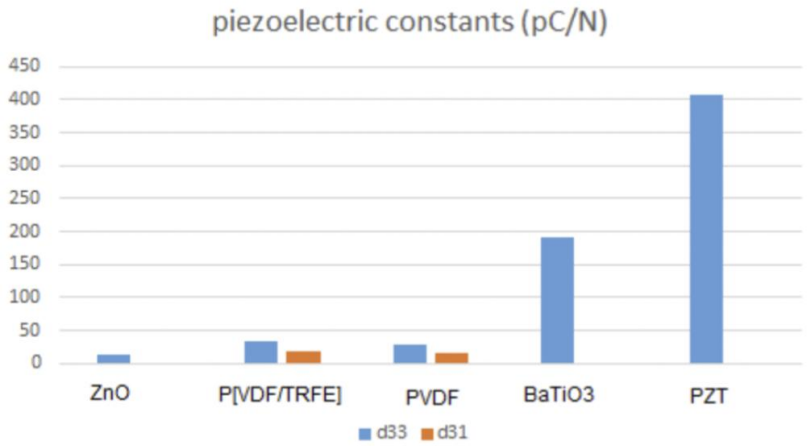

Figure 3.4 Piezoelectric coefficient range for some piezoelectric materials

4

IMPLEMENTATION

4.1 Software Implementation:

The main focus of the implementation is using the Arduino IDE to program the Arduino microcontroller with C/C++ code. To ascertain the soil's moisture content, the algorithm continuously examines inputs from the soil moisture sensor. To ensure automated garden watering, the system activates a relay to turn on the motor pump when the sensor indicates that the soil is dry. Integrated libraries maximize productivity by streamlining sensor data gathering and control procedures. Direct observation of sensor outputs allows for real-time monitoring and modification, allowing for responsive and sustainable energy consumption for efficient garden irrigation.

4.2 Hardware Implementation:

The system is made to assemble a lot of basic components. Use the energy produced by footsteps to provide enough water for the garden. The Arduino serves as the project's primary component, while the specification Uno serves as the primary controller unit. It is in charge of the overall plan. It is handled by means of control algorithms and interaction with various hardware components. By acting as a crucial switch, the relay enables control over high-voltage equipment like the motor pump, which distributes water. Depending on the needs of the system, the relay, which collaborates with the Arduino Uno, turns on or off the motor pump.. The device is powered by electrical energy that is converted from mechanical stress or pressure, such as footsteps in the garden, via piezoelectric sensor plates. The main power source is a 12V battery, which provides the voltage needed for every system component to

operate. Since it is a rechargeable battery, the energy produced by the piezo plates is used after the initial energy is used up. This adds to the setup's overall sustainability and efficiency by guaranteeing that the system will continue to function even if the initial energy is used up. A steady 5V output is provided by the Regulator 7805, which is essential for parts like the Arduino Uno. By showing the user the soil moisture level data and whether the motor is on or off, the 16x2 LED display gives visual feedback on the state and operation of the system. The required Hardware components for the project were stated in Table 4.1. The model can be viewed in Fig.4.1.

Table 4.1 Hardware Components

Hardware Components			
Sr.No.	Hardware Components	Specifications	Quantity
1	Arduino Uno	ATmega328	1
2	Relay	SPDT relay	1
3	Piezoelectric sensor plates	Sensor plates	6
4	Battery	12V lead-acid battery	1
5	Regulator	7805	1
6	LED Display	16x2	1
7	Sensor	Moisture Sensor	1
8	Resistor	1 KΩ	2
9	Potentiometer	250 KΩ	1
10	Push Button		3
11	Breadboard		1
12	Motor Pump		1
13	Motor Driver		1
14	NPN Transistor		1
15	Diode		2

Additionally, the Arduino Uno MCU can regulate the motor pump's activity based on the specified threshold due to the moisture sensor, which tracks the soil's moisture content.

Combining these elements not only makes irrigation more effective but also maximizes energy efficiency and prolongs system life. The technology makes sure the garden gets the right amount of water by utilizing automation and real-time data, which minimizes waste and conserves resources. Consistent performance and dependability require routine calibration and maintenance of the sensors and other parts. These actions are essential for adjusting to shifting environmental conditions and making sure the system keeps working well over time. These parts work together to create a seamless and effective irrigation system that maximizes garden watering while using less water and electricity.

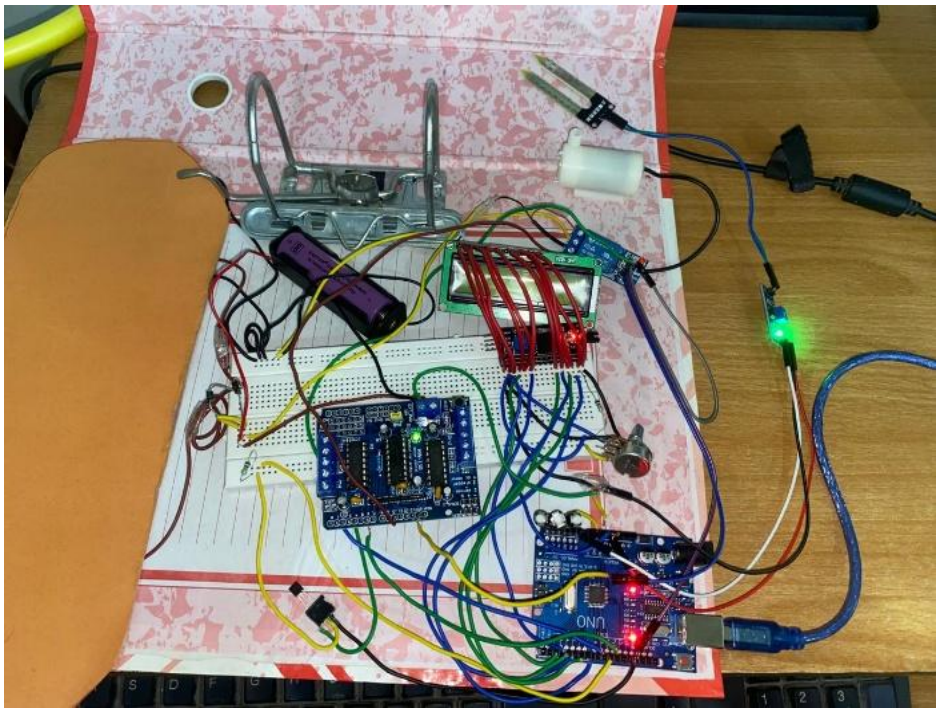

Figure 4.1 Implemented hardware model of piezoelectric footstep power harvesting

4.3 State of the Art Implementation:

With the use of piezoelectric modules built inside commuter bicycles, Jettanasen et al. concentrate on harnessing the mechanical energy of cycling to produce electrical power. By converting kinetic energy into electrical energy, this technique promotes urban mobility and sustainable energy. According to experimental data, 13.6 mW is produced at typical cycling speeds, making it appropriate for low-power sensors and gadgets. [20] Unlike the earlier work, the current project focuses on exploiting mechanical energy from walking and running, primarily in densely populated areas, to create electricity from the footsteps. This electricity will be used for irrigating fields and rural mobility sustainability. For automatic irrigation, piezoelectric sensors use mechanical energy capture in conjunction with real-time soil moisture data.

Mali et al. charged the mobile phone using energy from piezoelectric plates. Piezoelectric plates are used in the electronics industry for mobile charging. To increase the efficiency of piezoelectric charging technology for sustainability, more innovation is required. Thus, this is in contradiction to the planned work. [21] There is potential for energy sustainability and innovation in agriculture with the incorporation of piezoelectric sensors for water conservation in plant irrigation; however, the use of the generated energy differs from the [21]. In agriculture, irrigation and energy production are maximized using piezoelectric energy harvesting and soil moisture sensing.

4.4 Limitations:

It works in specific locations that are not always accessible and for a brief geographic area. Batteries should have their power and voltage thresholds addressed. The amount of foot pressure and the location of the sensor may limit the energy generation efficiency of piezoelectric sensors. Continuous operation may be limited by the 12V battery's capacity and longevity when utilized as the main power source, especially when foot traffic is minimal.

5

RESULTS AND DISCUSSION

In essence, the piezoelectric sensors could generate electrical voltage in response to mechanical stress, such as footfall, when pressure was applied. A bridge rectifier was used to transform the actual AC voltage that was received from the sensors into a DC voltage, which was subsequently used to charge a rechargeable battery. Overall, during the testing period, it demonstrated the system's capacity to generate and store electrical energy to power the irrigation system's control electronics and soil moisture sensor. The autonomous gardening system now has a renewable energy source due to the energy collecting and energy storage idea.

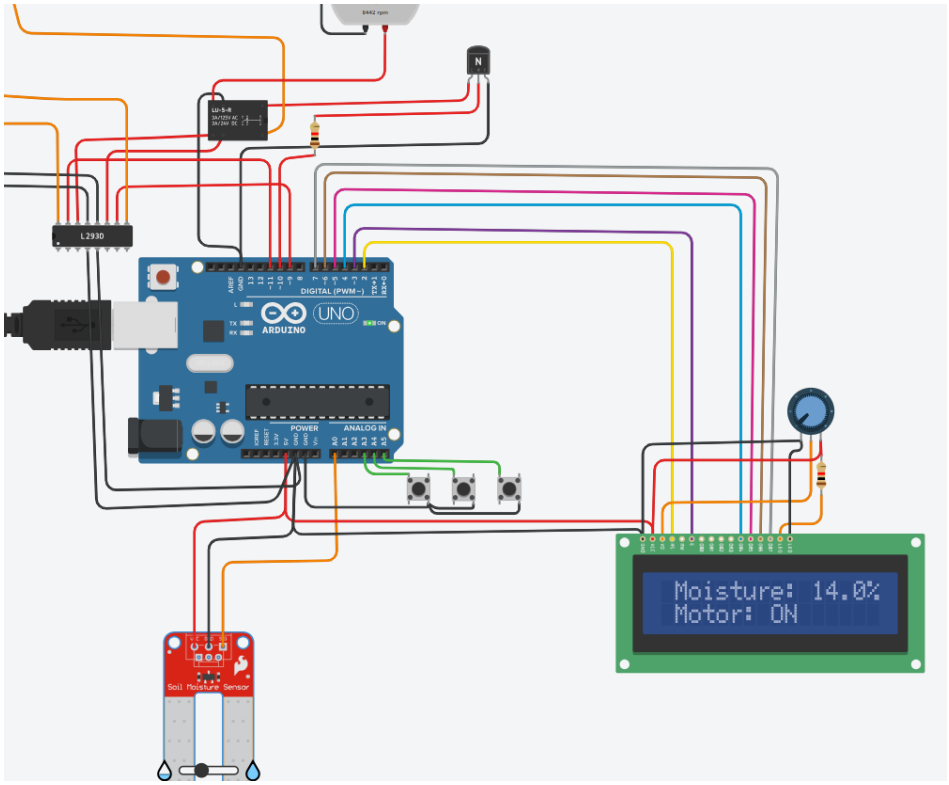

Figure 5.1 Software results for low moisture level when motor is on

In order to obtain precise readings for the “dry” and “wet” conditions of the soil, the soil moisture sensor has been calibrated. Once the soil was dry, the sensor successfully activated the watering system, as demonstrated during the testing phase (See Fig. 5.1 and Fig. 5.2). To ensure a sufficient supply of water for the plants without wasting it, the system used the water that was already being used, such as the water used to wash vegetables and the water used in the kitchen to make starch from boiled rice. The soil’s moisture content was maintained at or near the level needed for plant growth. As instructed, it began watering and stopped as soon as the proper moisture content was reached.

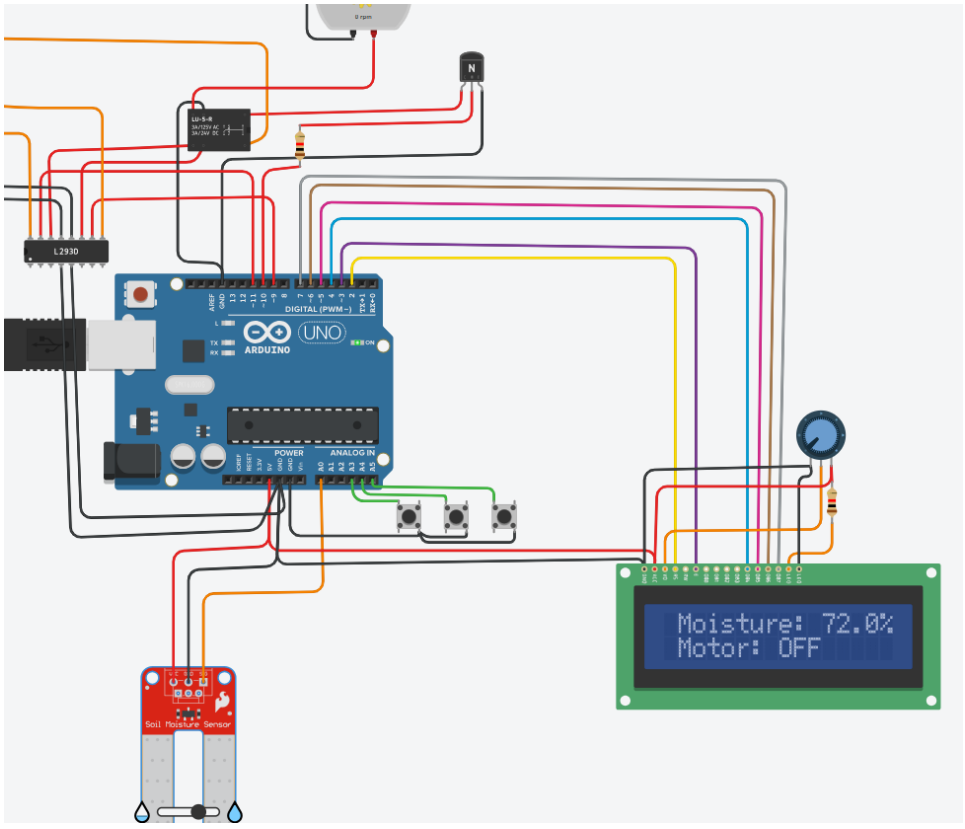

Figure 5.2 Software results for high moisture level when motor is off

Figure 5.3 Displaying result of the sensor

The method offered the combined advantages of effective water management and the use of renewable energy by combining smart irrigation with piezoelectric energy harvesting. The design's emphasis on conservation was further highlighted by the usage of recycled water. In comparison to conventional irrigation techniques, the system decreased overall water consumption by about 30 % during a one-month test period. At the same time, using energy produced by footsteps decreased reliance on outside power sources to regulate the garden's irrigation. Fig. 5.3 shows the hardware implementation result of the system. While fig 5.4 shows the status of dry soil sensed by moisture sensor which is required to be irrigated and motor is on.

Figure 5.4 Dry Soil sensed and motor is on

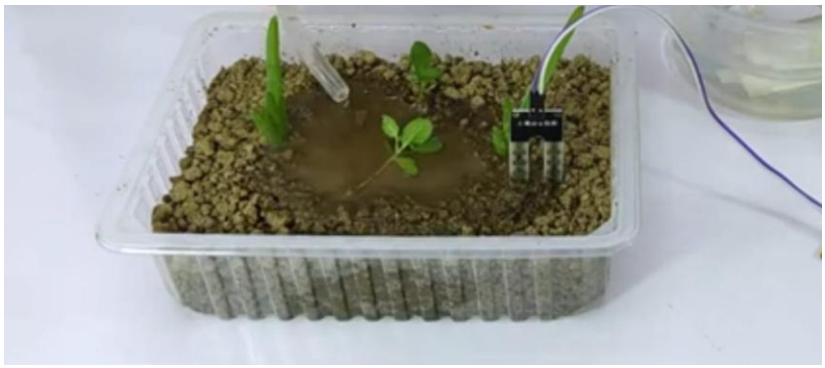

Figure 5.5 Wet soil sensed and motor is off

Fig 5.5 shows the status of wet soil sensed by moisture sensor which is required not to be irrigated further and motor is off.

6

CONCLUSIONS AND FUTURE SCOPES WITH REFERENCES

In order to maximize irrigation and energy production in agricultural contexts, the project effectively integrates soil moisture detection and piezoelectric energy harvesting. Through the use of real-time soil moisture data and mechanical energy captured from foot activity, the system automates watering, greatly enhancing resource efficiency and water management. Water waste is reduced and sustainable farming methods are supported when irrigation is modified in accordance with the actual soil conditions. This strategy emphasizes efficiency and resource conservation, which is in line with contemporary farming objectives. Piezoelectric sensor's integration demonstrates their potential to improve energy sustainability and spur agricultural technology innovation, opening the door to more self-sufficient and environmentally friendly farming methods.

In order to provide real-time data modeling and deliver alarm alerts for thresholds, future work will integrate cloud services and platforms such as ThingSpeak. To increase the efficiency of energy generation, more advanced piezoelectric materials with higher capacities will be investigated. By customizing irrigation to real-time data and user preferences, machine learning algorithms and sensor fusion techniques will further optimize irrigation and improve the system's overall efficiency and adaptability.

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